(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 538 474 A3

# (12) EUROPEAN PATENT APPLICATION

(88) Date of publication A3:
**17.12.2014 Bulletin 2014/51**

(43) Date of publication A2:
**26.12.2012 Bulletin 2012/52**

(21) Application number: **12172989.1**

(22) Date of filing: **21.06.2012**

(51) Int Cl.:
***H01M 4/86*** *(2006.01)* ***H01M 4/90*** *(2006.01)*
***H01M 8/12*** *(2006.01)*

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
**BA ME**

(30) Priority: **21.06.2011 KR 20110060232**

(71) Applicant: **Samsung Electro-Mechanics Co., Ltd**
**Suwon-si, Gyeonggi-do (KR)**

(72) Inventors:
- **Seo, Soo-yeon**
  **Gyeonggi-do, (KR)**
- **Kwak, Chan**
  **Gyeonggi-do, (KR)**
- **Park, Hee-jung**
  **Gyeonggi-do (KR)**

(74) Representative: **Zijlstra, Robert Wiebo Johan**
**Elkington and Fife LLP**
**Prospect House**
**8 Pembroke Road**
**Sevenoaks, Kent TN13 1XR (GB)**

## (54) Material for solid oxide fuel cell, cathode including the material, and solid oxide fuel cell including the material

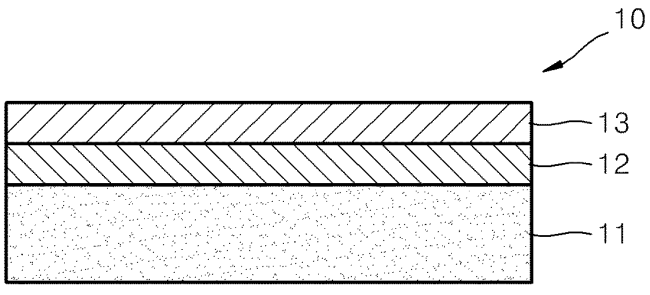
(57) A material for a solid oxide fuel cell, the material including: a first compound having a perovskite crystal structure, a first ionic conductivity, a first electronic conductivity, and a first thermal expansion coefficient, wherein the first compound is represented by Formula 1 below; and a second compound having a perovskite crystal structure, a second ionic conductivity, a second electronic conductivity, and a second thermal expansion coefficient,

Formula 1

$$Ba_aSr_bCo_xFe_yZ_{1-x-y}O_{3-\delta},$$

wherein
Z is a transition metal element, a lanthanide element, or a combination thereof,
a and b satisfy $0.4 \le a \le 0.6$ and $0.4 \le b \le 0.6$, respectively,
x and y satisfy $0.6 \le x \le 0.9$ and $0.1 \le y \le 0.4$, respectively, and
$\delta$ is selected so that the first compound is electrically neutral.

FIG. 1




EP 2 538 474 A3

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 12 17 2989

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| X | US 2009/305090 A1 (CHUANG STEVEN S C [US]) 10 December 2009 (2009-12-10)<br>* claims 1,2 *<br>* paragraphs [0056], [0009], [0010] * | 1 | INV.<br>H01M4/86<br>H01M4/90<br>H01M8/12 |
| Y | EP 0 639 866 A1 (WESTINGHOUSE ELECTRIC CORP [US]) 22 February 1995 (1995-02-22)<br>* column 1, line 34 - column 2, line 23 * | 1-14 | |
| Y | CN 101 752 585 A (UNIV NANJING) 23 June 2010 (2010-06-23)<br>* paragraph [0012] * | 1-14 | |
| T | JP 2011 096617 A (NAT INST OF ADVANCED IND SCIEN) 12 May 2011 (2011-05-12)<br>* paragraphs [0023], [0024] * | | |
| T | EP 0 552 055 A2 (NGK INSULATORS LTD [JP]) 21 July 1993 (1993-07-21)<br>* paragraph [0037] * | | |
| A | US 2005/271931 A1 (FINNERTY CAINE [US]) 8 December 2005 (2005-12-08)<br>* paragraph [0052] * | 11 | TECHNICAL FIELDS SEARCHED (IPC)<br>H01M |
| A | WO 2010/136816 A1 (ULIVE ENTPR LTD [GB]; ROSSEINSKY MATTHEW [GB]; NIU HONGJUN [GB]; CLARI) 2 December 2010 (2010-12-02)<br>* table 6; compound 2 *<br>* example 3 *<br>* page 16, lines 22-35 * | 1-14 | |
| A | CN 101 222 060 A (UNIV BEIJING SCIENCE & TECH [CN]) 16 July 2008 (2008-07-16)<br>* page 2, paragraphs 2,3 * | 1-14 | |

-/--

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 6 November 2014 | Reich, Claus |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

Europäisches Patentamt
European Patent Office
Office européen des brevets

# EUROPEAN SEARCH REPORT

Application Number
EP 12 17 2989

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|---|---|---|---|
| A | CN 101 596 414 A (UNIV SOUTH CHINA TECH [CN]) 9 December 2009 (2009-12-09) * tables 2,3 * | 1-14 | |
| A | US 2009/291347 A1 (SUZUKI TOSHIO [JP] ET AL) 26 November 2009 (2009-11-26) * paragraphs [0041], [0044] * | 1-14 | |
| X | WO 2011/001930 A1 (HONDA MOTOR CO LTD [JP]; KOIZUMI ATSUSHI [JP]) 6 January 2011 (2011-01-06) * paragraphs [0034] - [0046] * | 15 | |
| A | EP 1 458 043 A1 (GEN ELECTRIC [US]) 15 September 2004 (2004-09-15) * paragraph [0026] * | 15 | |
| A | EP 2 030 673 A1 (UNIV DENMARK TECH DTU [DK]) 4 March 2009 (2009-03-04) * table 1 * | 15 | |
| | | | TECHNICAL FIELDS SEARCHED (IPC) |

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 6 November 2014 | Reich, Claus |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

Europäisches Patentamt
European Patent Office
Office européen des brevets

Application Number
EP 12 17 2989

## CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

## LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

Europäisches Patentamt
European Patent Office
Office européen des brevets

## LACK OF UNITY OF INVENTION
## SHEET B

Application Number
EP 12 17 2989

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 2-14(completely); 1(partially)

A cathode material for a solid oxide fuel cell comprising:
a first compound having a perovskite crystal structure, a first ionic conductivity, a first electronic conductivity, and a first thermal expansion coefficient, wherein the first compound is represented by
BaaSrbCOxFeyZ1-x-yO3-[delta], wherein
Z is a transition metal element, a lanthanide element, or a combination thereof,
a and b satisfy 0.4 <= a <= 0.6 and 0.4 <= b <= 0.6, respectively,
x and y satisfy 0.6 <= x <= 0.9 and 0.1 <= y <= 0.4, respectively, and
[delta] is selected so that the first compound is electrically neutral; and
a second compound having a perovskite crystal structure, a second ionic conductivity, a second electronic conductivity, and a second thermal expansion coefficient,wherein the first ionic conductivity is more than the second ionic conductivity, the first electronic conductivity is less than the second electronic conductivity, and the first thermal expansion coefficient is more than the second thermal expansion coefficient, wherein the second compound is represented by
the compound LacSrdCowFezO3-[gamma], wherein
c and d satisfy 0.5 <= c <= 0.7 and 0.3 <= d <= 0.5, respectively,
w and z satisfy 0.1 <= w <= 0.3 and 0.7 <= z <= 0.9, respectively, and
[gamma] is selected so that the second compound is electrically neutral;
or the compound AeSrfCoqMrO3-[zeta], wherein
A is lanthanum, samarium, praseodymium, or a combination thereof,
M is iron, manganese, or a combination thereof,
e and f satisfy 0.4 <= e <= 0.8 and 0.2 <= f <= 0.6, respectively,
q and r satisfy 0 <= q <= 0.9 and 0.1 <= r <= 1, respectively,
provided that when A and M are lanthanum and iron, respectively, q = 0, and
[zeta] is selected so that the second compound is electrically neutral.

---

2. claims: 15(completely); 1(partially)

A solid oxide fuel cell comprising a cathode, an anode, an electrolyte interposed between the cathode and the anode and a functional layer interposed between the cathode and the

Europäisches Patentamt
European Patent Office
Office européen des brevets

## LACK OF UNITY OF INVENTION
## SHEET B

Application Number
EP 12 17 2989

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

electrolyte, wherein the functional layer comprises:
a first compound having a perovskite crystal structure, a first ionic conductivity, a first electronic conductivity, and a first thermal expansion coefficient, wherein the first compound is represented by
BaaSrbCOxFeyZ1-x-yO3-[delta], wherein
Z is a transition metal element, a lanthanide element, or a combination thereof,
a and b satisfy 0.4 <= a <= 0.6 and 0.4 <= b <= 0.6, respectively,
x and y satisfy 0.6 <= x <= 0.9 and 0.1 <= y <= 0.4, respectively, and
[delta] is selected so that the first compound is electrically neutral; and
a second compound having a perovskite crystal structure, a second ionic conductivity, a second electronic conductivity, and a second thermal expansion coefficient,wherein the first ionic conductivity is more than the second ionic conductivity, the first electronic conductivity is less than the second electronic conductivity, and the first thermal expansion coefficient is more than the second thermal expansion coefficient, wherein the second compound is represented by
the compound LacSrdCowFezO3-[gamma], wherein
c and d satisfy 0.5 <= c <= 0.7 and 0.3 <= d <= 0.5, respectively,
w and z satisfy 0.1 <= w <= 0.3 and 0.7 <= z <= 0.9, respectively, and
[gamma] is selected so that the second compound is electrically neutral;
or the compound AeSrfCoqMrO3-[zeta], wherein
A is lanthanum, samarium, praseodymium, or a combination thereof,
M is iron, manganese, or a combination thereof,
e and f satisfy 0.4 <= e <= 0.8 and 0.2 <= f <= 0.6, respectively,
q and r satisfy 0 <= q <= 0.9 and 0.1 <= r <= 1, respectively,
provided that when A and M are lanthanum and iron, respectively, q = 0, and
[zeta] is selected so that the second compound is electrically neutral (second functional layer).

---

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 17 2989

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-11-2014

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| US 2009305090 A1 | 10-12-2009 | AU 2007294812 A1 | 20-03-2008 |
| | | CN 101601154 A | 09-12-2009 |
| | | EA 200970278 A1 | 30-04-2010 |
| | | EP 2059965 A2 | 20-05-2009 |
| | | US 2009305090 A1 | 10-12-2009 |
| | | WO 2008033421 A2 | 20-03-2008 |
| EP 0639866 A1 | 22-02-1995 | CA 2117507 A1 | 17-02-1995 |
| | | DE 69403294 D1 | 26-06-1997 |
| | | DE 69403294 T2 | 11-12-1997 |
| | | EP 0639866 A1 | 22-02-1995 |
| | | JP H0794191 A | 07-04-1995 |
| | | TW 266334 B | 21-12-1995 |
| CN 101752585 A | 23-06-2010 | NONE | |
| JP 2011096617 A | 12-05-2011 | JP 5327807 B2 | 30-10-2013 |
| | | JP 2011096617 A | 12-05-2011 |
| EP 0552055 A2 | 21-07-1993 | DE 69304353 D1 | 10-10-1996 |
| | | DE 69304353 T2 | 20-02-1997 |
| | | EP 0552055 A2 | 21-07-1993 |
| | | JP 2527876 B2 | 28-08-1996 |
| | | JP H05198304 A | 06-08-1993 |
| | | US 5281490 A | 25-01-1994 |
| US 2005271931 A1 | 08-12-2005 | NONE | |
| WO 2010136816 A1 | 02-12-2010 | AU 2010252753 A1 | 01-12-2011 |
| | | CA 2761867 A1 | 02-12-2010 |
| | | EP 2436072 A1 | 04-04-2012 |
| | | JP 2012528438 A | 12-11-2012 |
| | | KR 20120016293 A | 23-02-2012 |
| | | US 2012135331 A1 | 31-05-2012 |
| | | WO 2010136816 A1 | 02-12-2010 |
| CN 101222060 A | 16-07-2008 | NONE | |
| CN 101596414 A | 09-12-2009 | NONE | |
| US 2009291347 A1 | 26-11-2009 | JP 5317274 B2 | 16-10-2013 |
| | | JP 2010003669 A | 07-01-2010 |
| | | US 2009291347 A1 | 26-11-2009 |
| WO 2011001930 A1 | 06-01-2011 | JP 5547188 B2 | 09-07-2014 |
| | | WO 2011001930 A1 | 06-01-2011 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

## ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 17 2989

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-11-2014

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
| EP 1458043 A1 | 15-09-2004 | CA 2459693 A1 | 14-09-2004 |
| | | EP 1458043 A1 | 15-09-2004 |
| | | JP 2004281400 A | 07-10-2004 |
| | | US 2004180252 A1 | 16-09-2004 |
| EP 2030673 A1 | 04-03-2009 | CN 101795756 A | 04-08-2010 |
| | | EP 2030673 A1 | 04-03-2009 |
| | | EP 2183044 A1 | 12-05-2010 |
| | | US 2011132772 A1 | 09-06-2011 |
| | | WO 2009027101 A1 | 05-03-2009 |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82